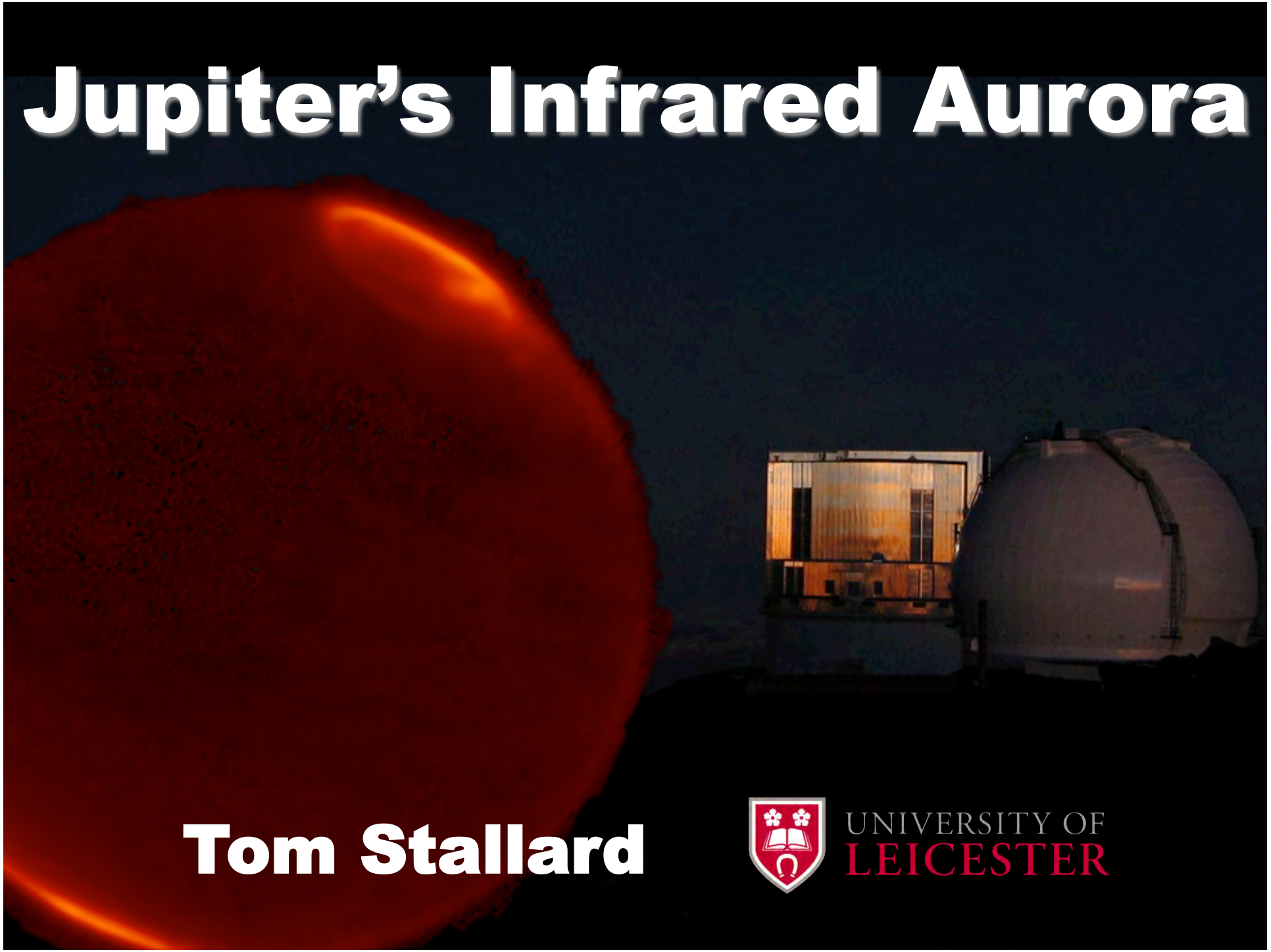
Jupiter's Infrared Aurora

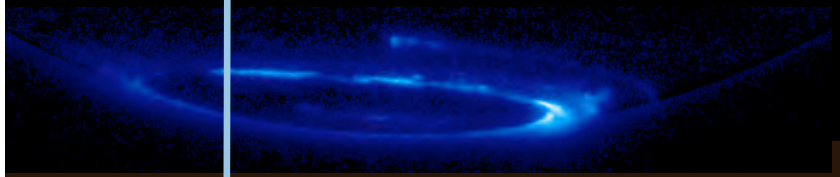


Tom Stallard

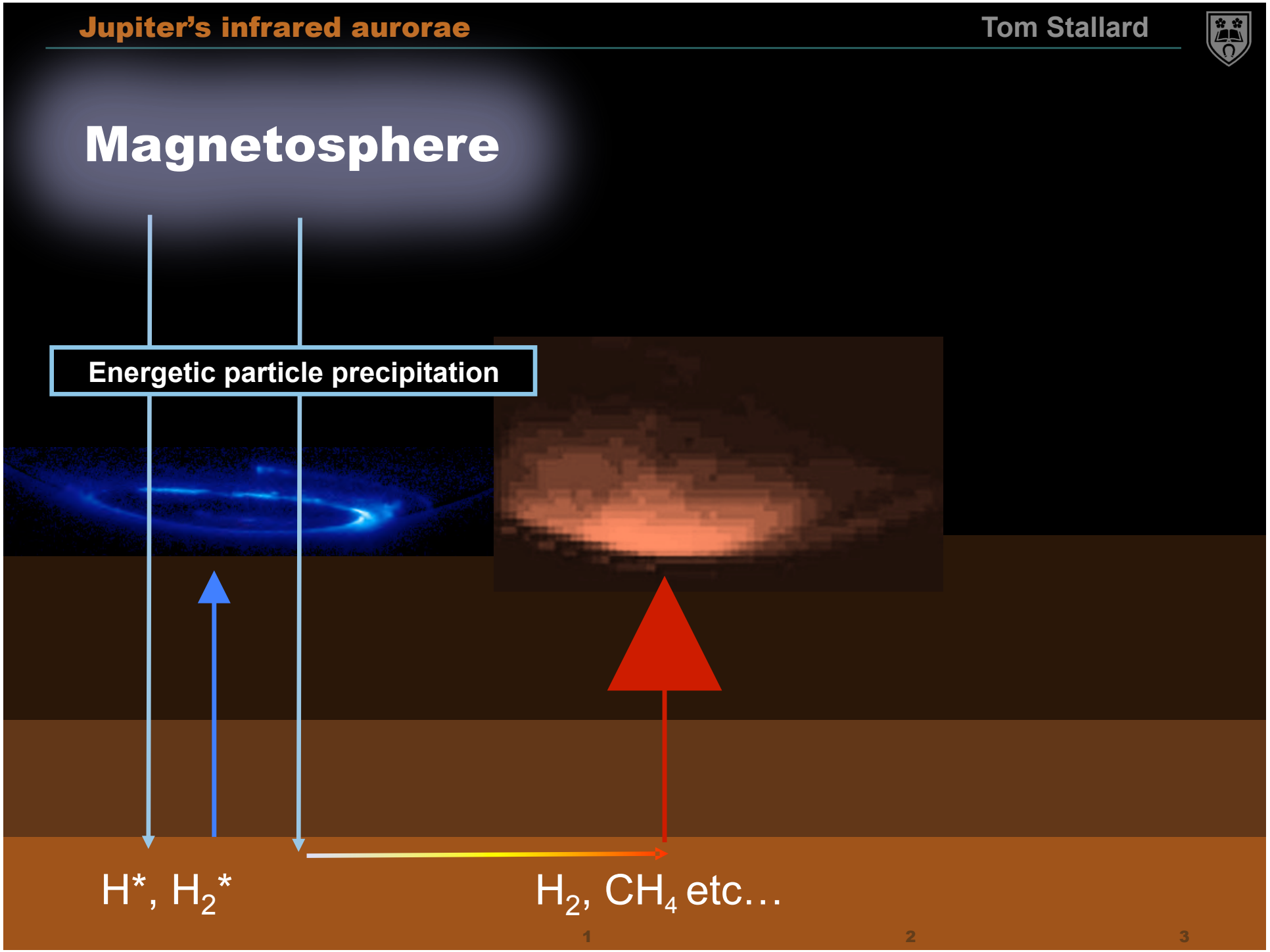
UNIVERSITY OF LEICESTER

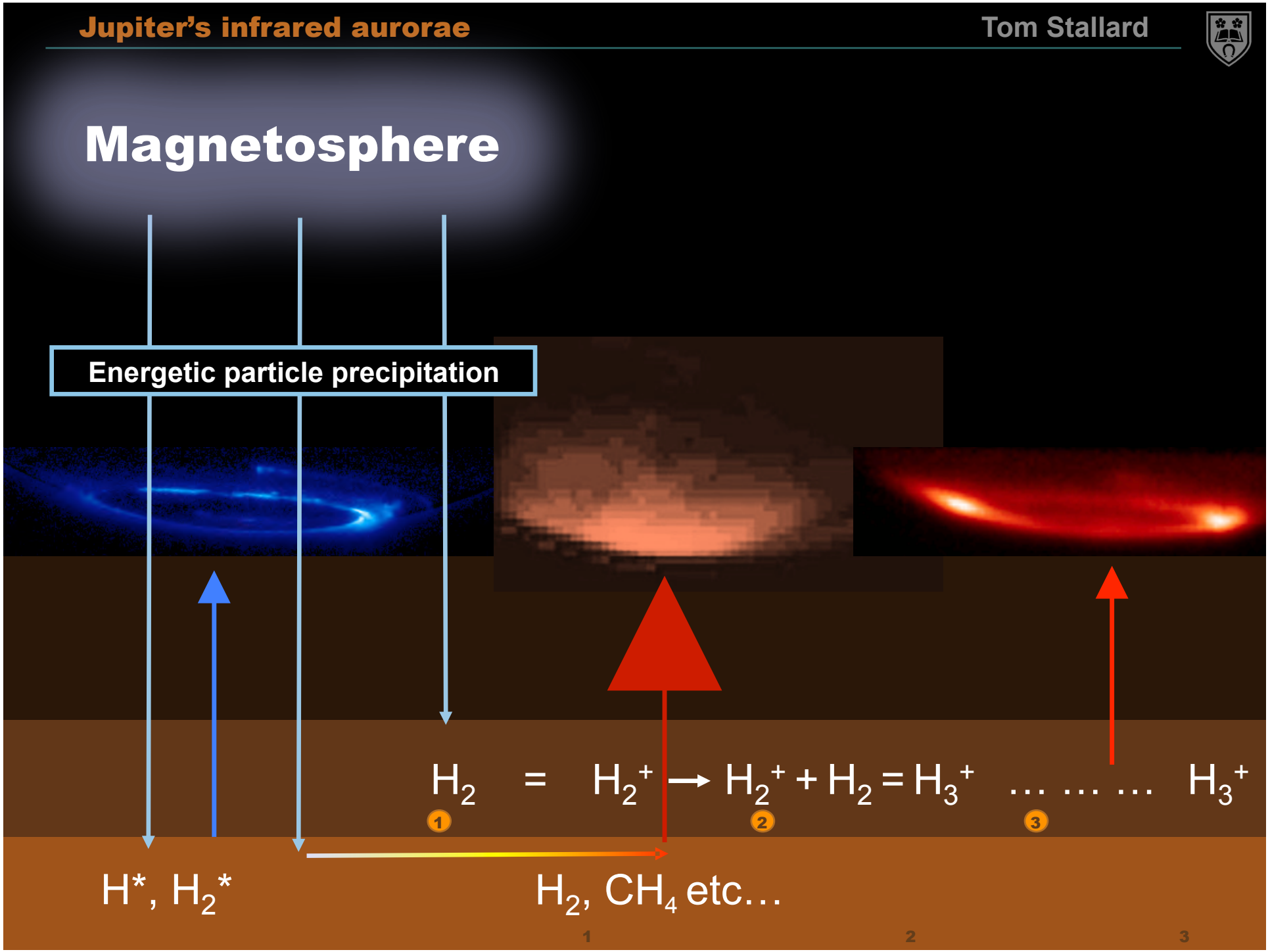
Magnetosphere

Energetic particle precipitation



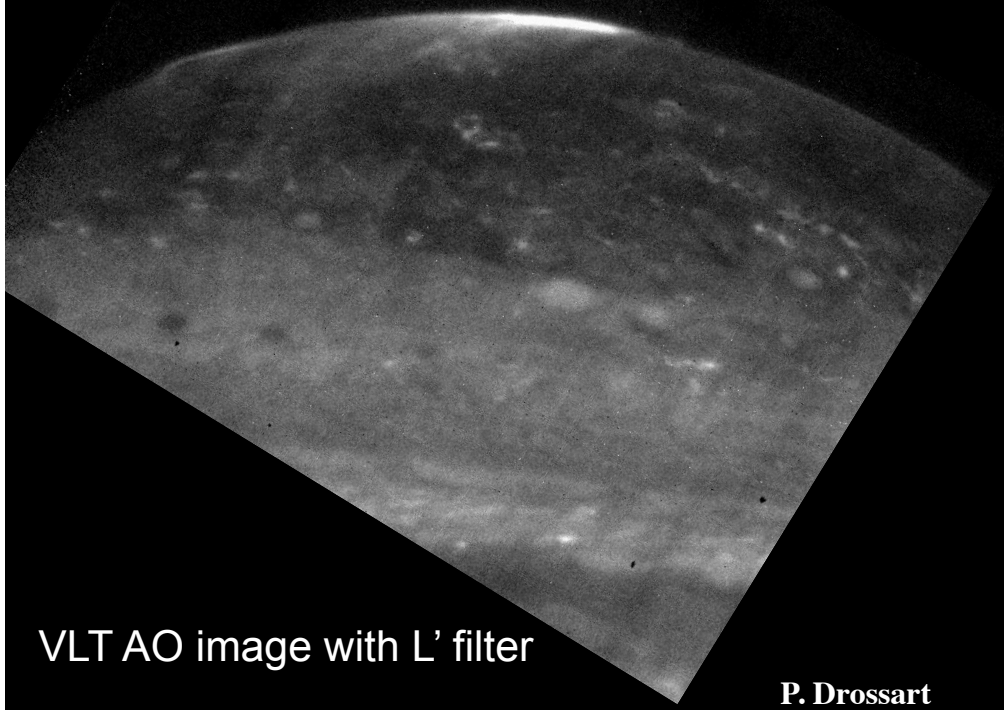
H^*, H_2^*


Magnetosphere
Energetic particle precipitation
H*, H2*
H2, CH4 etc…
1
2
3


Magnetosphere
Energetic particle precipitation
H_2 = H_2^+ → $H_2^+ + H_2 = H_3^+$ … … … H_3^+
1 2 3
H*, H_2*
H_2, CH_4 etc…
1 2 3

Infrared observations

T. Stallard



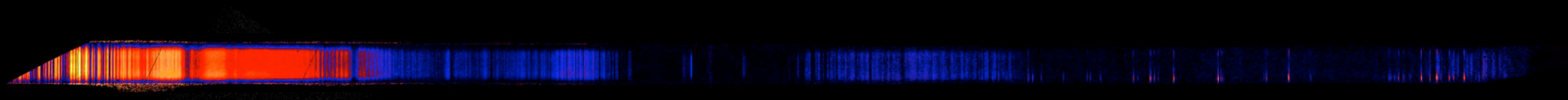
VLT AO image with L' filter

P. Drossart

IRTF 3.53μm narrow filter

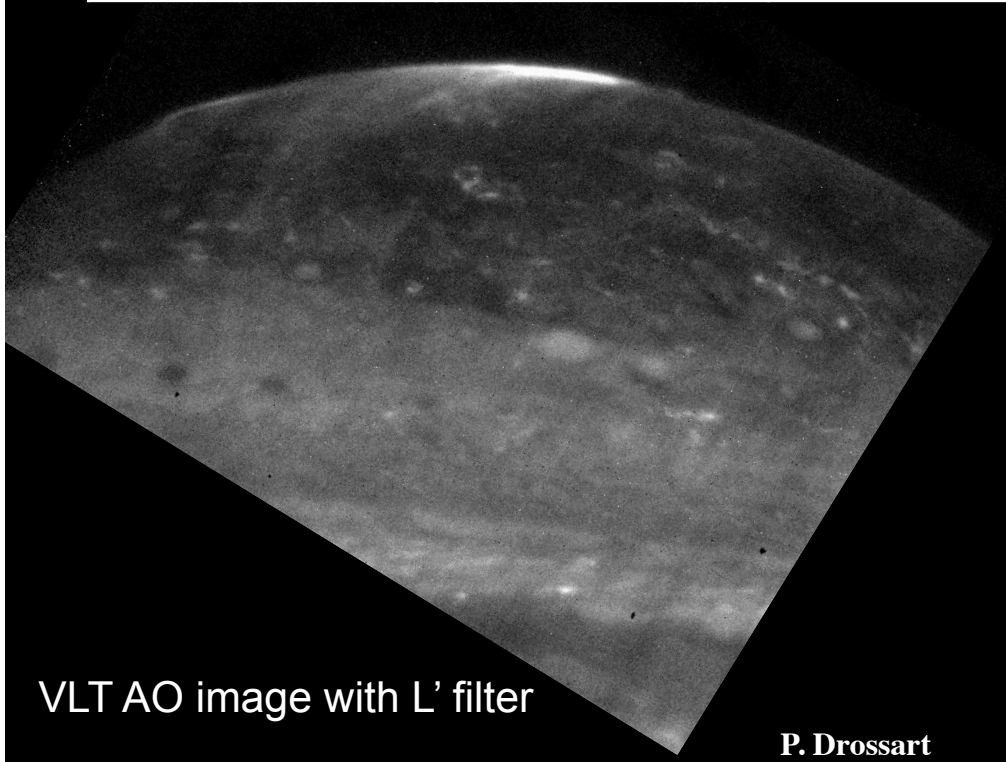
J. Connerney

Infrared observations



T. Stallard

near IR	Orton	IRTF/MORIS, SpeX spectrometer	filtered imaging and spectral scans: 0.8-2.5μm, 2.5-5.1μm (SpeX)	Ongoing throughout Juno mission



VLT AO image with L' filter

P. Drossart

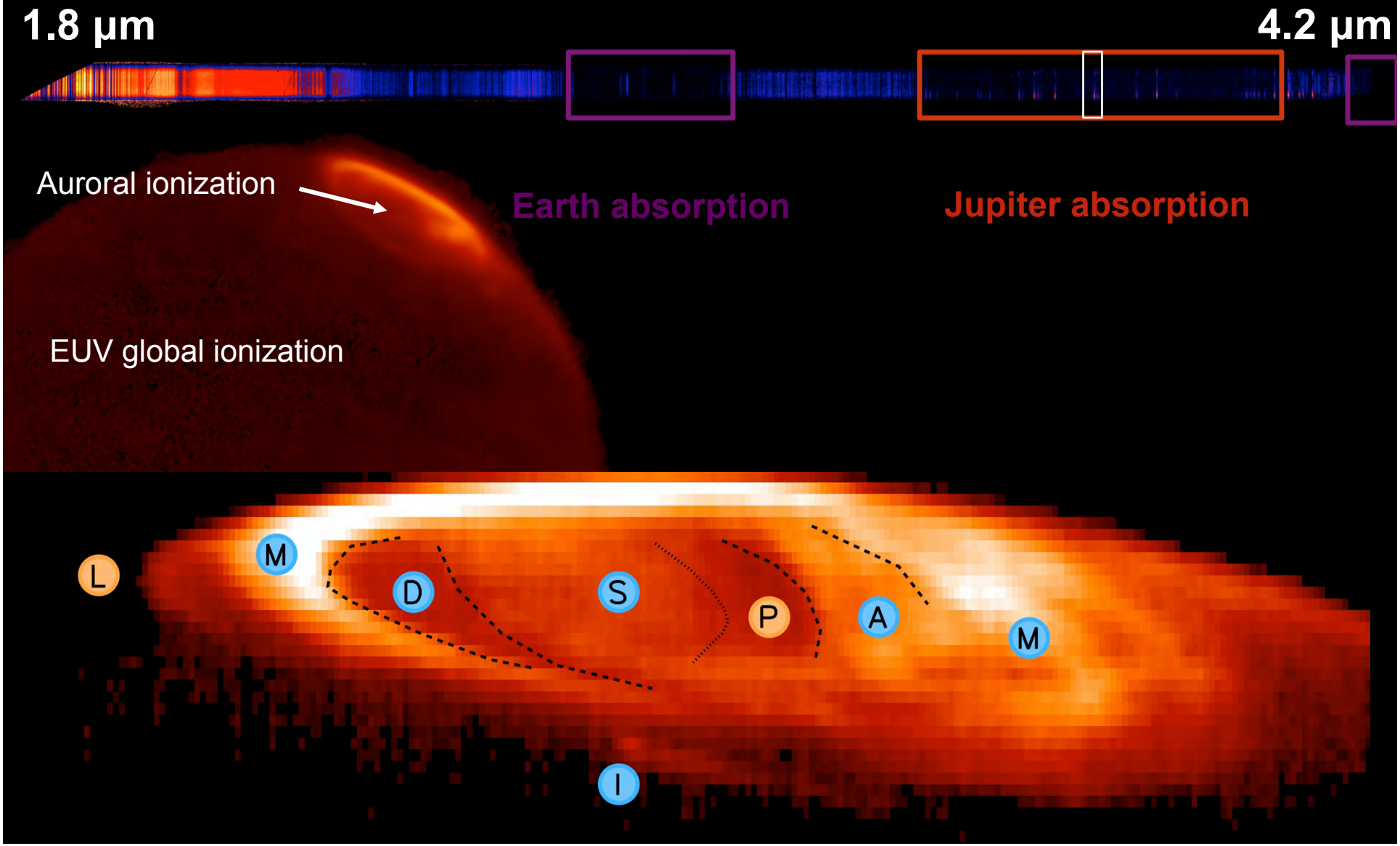
IRTF 3.53μm narrow filter

J. Connerney

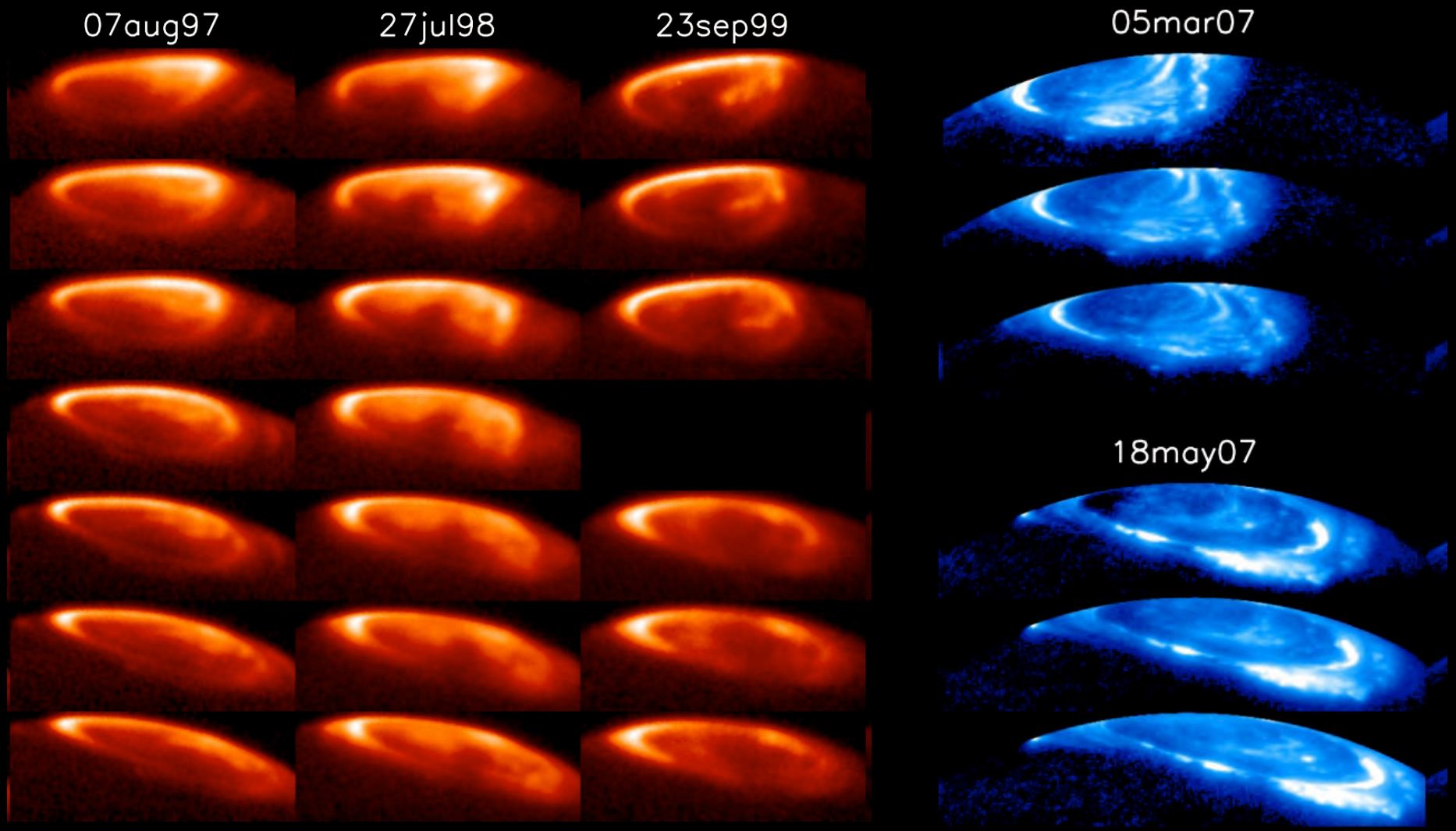
Bonfond	VLT / NACO	AO-imaging of H_3^+ emission	service observations to cover ten 1-hour sessions in Apr, May

near IR	Orton	IRTF/SpeX guide camera	filtered auroral imaging in 20- to 30-min intervals	Ongoing throughout Juno mission

2-5 micron H_3^+ emission



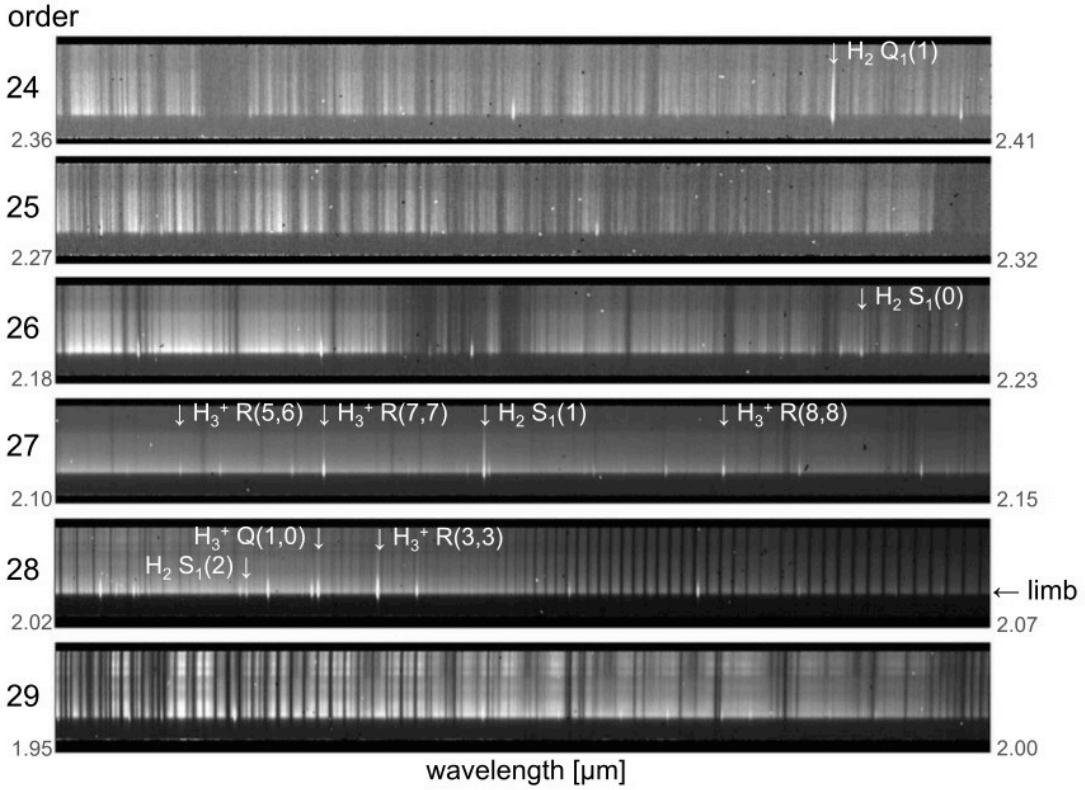
Timescale of IR emission

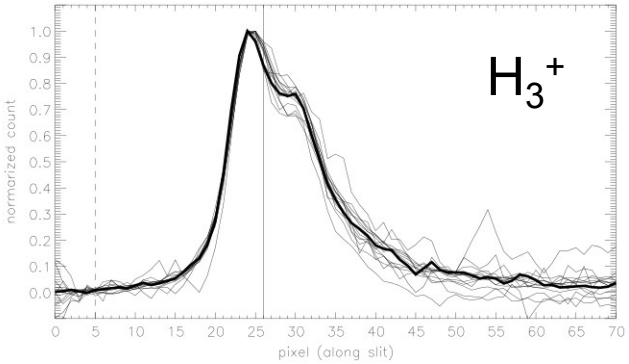


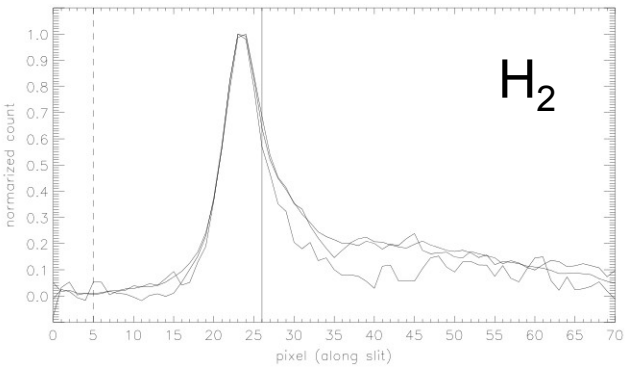
Stallard et al., 2016

2 micron altitudinal emission

Peak emission at 400-700km



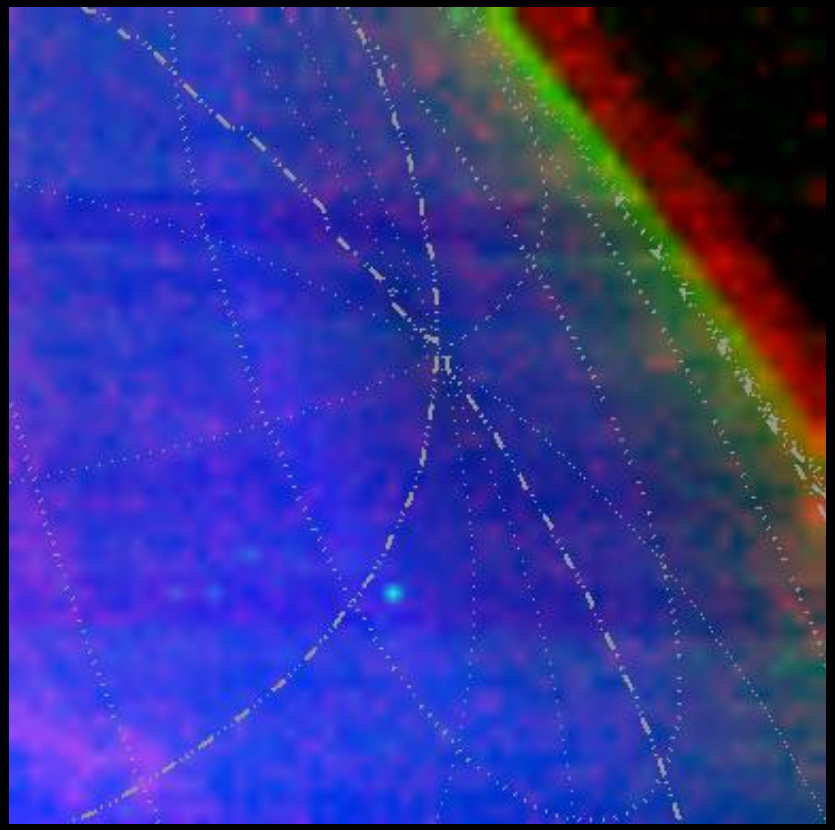


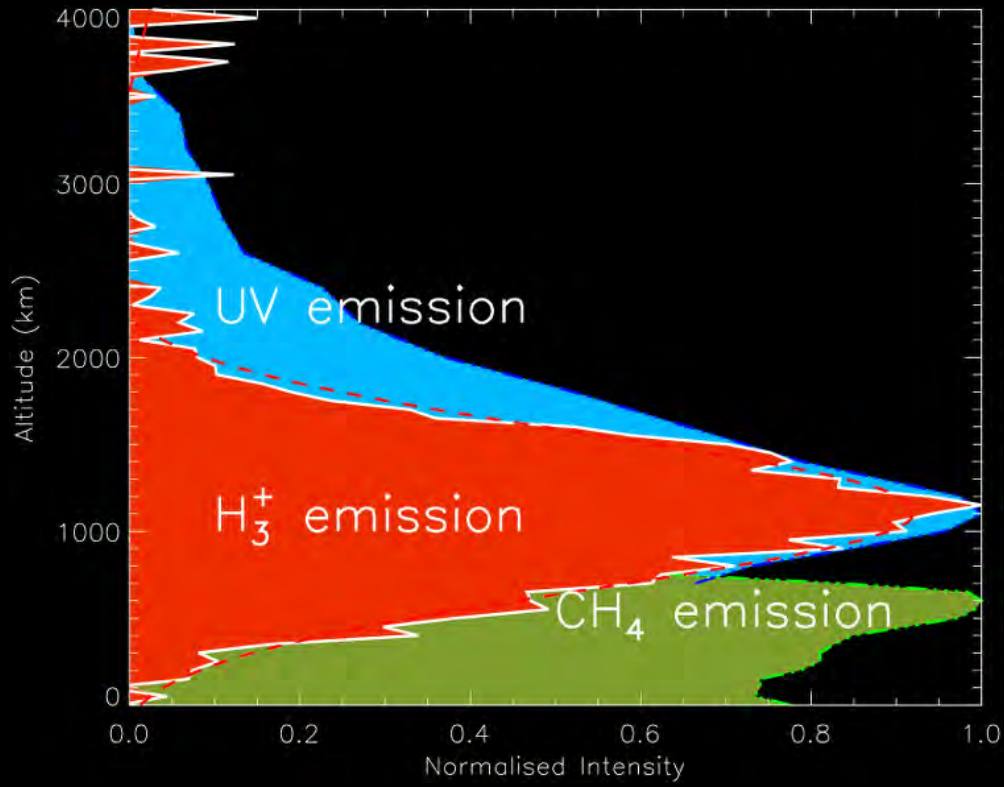


Uno et al., 2014

near IR	Kasaba	Subaru / IRCS	AO-guided imaging/ spectroscopy of H3+ emission	scheduled: May 19, 21, 24

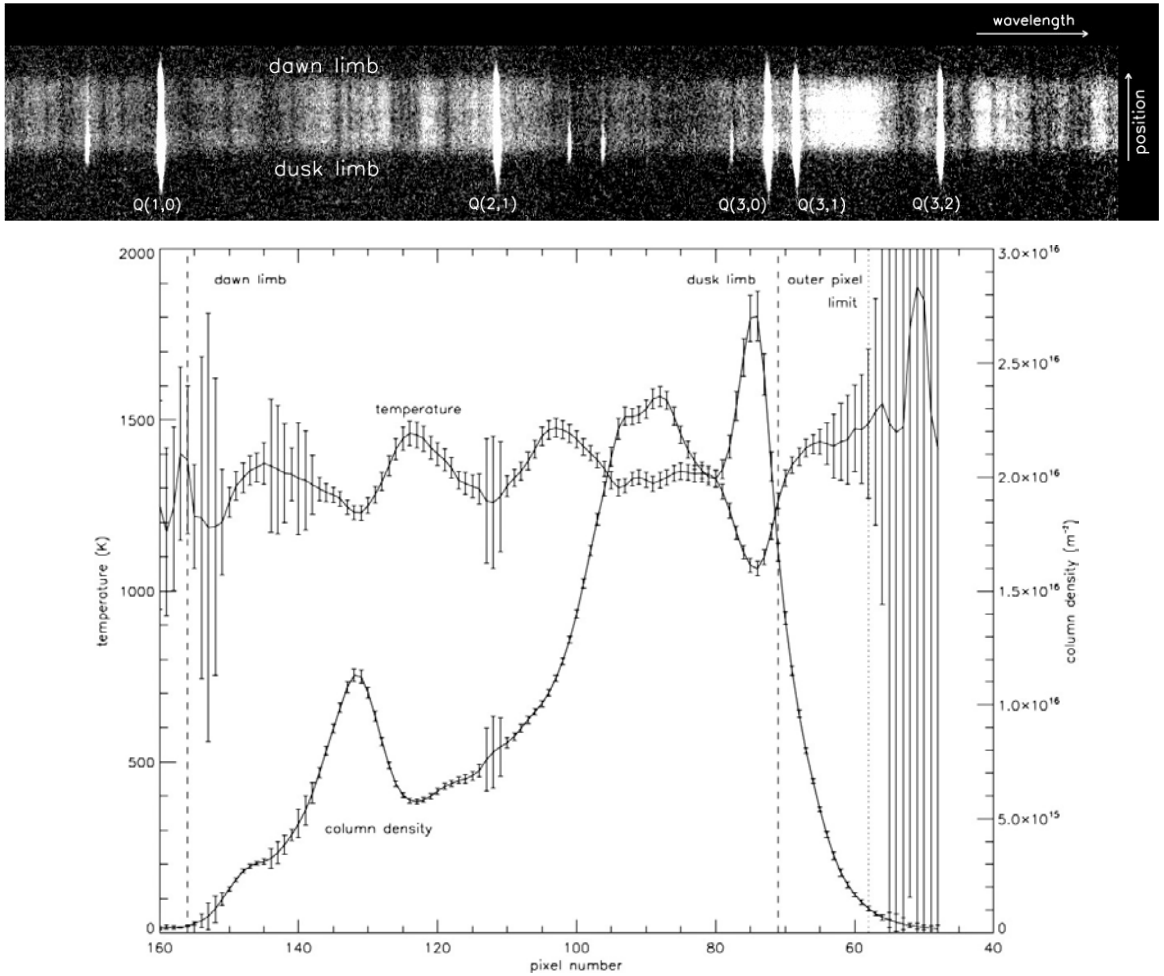
Saturn's altitudinal emission



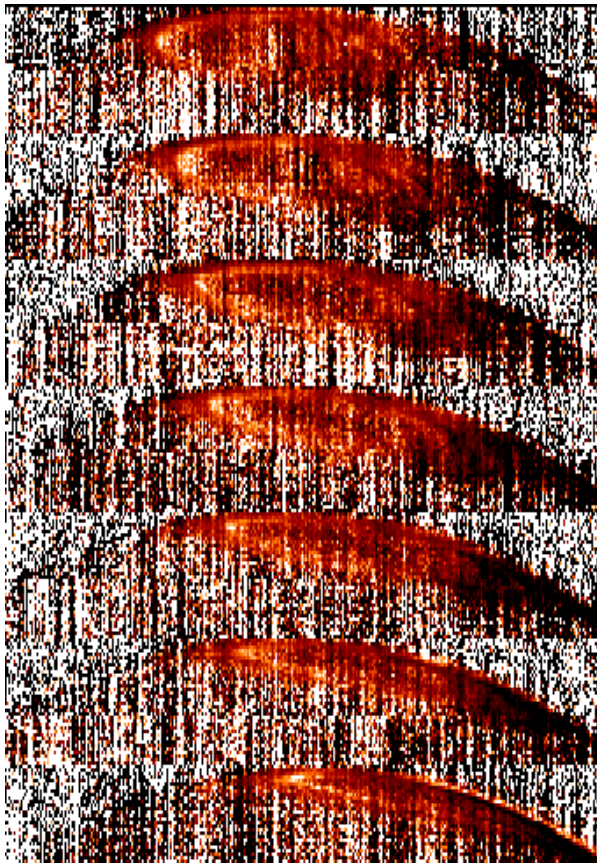


Gerard et al. 2009; Stallard et al., 2012

Temperatures and Densities



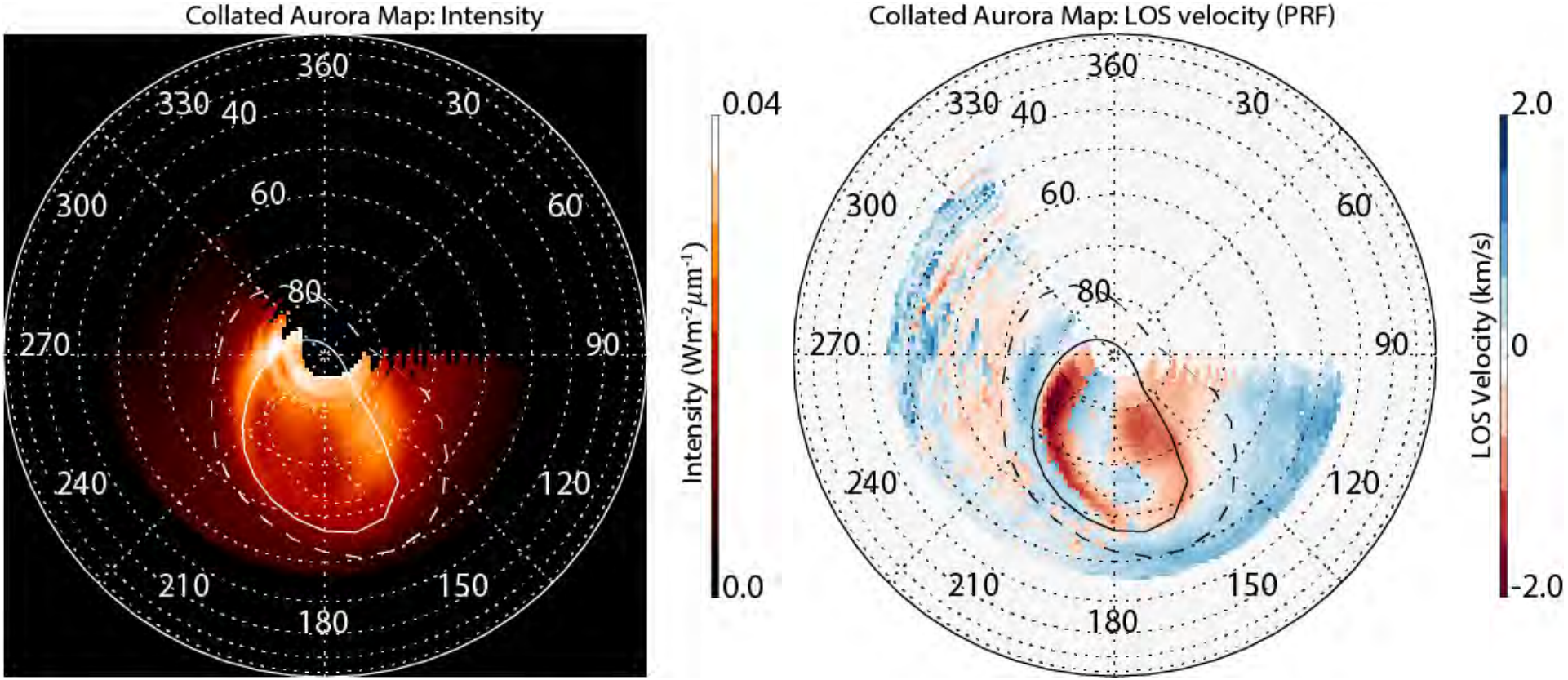
Lystrup, 2008



Stallard/Johnson

near IR	O'Donoghue	Keck / NIRSpec	high-spectral resolution scanning of H3+ aurorae	scheduled for 4 half nights in May.

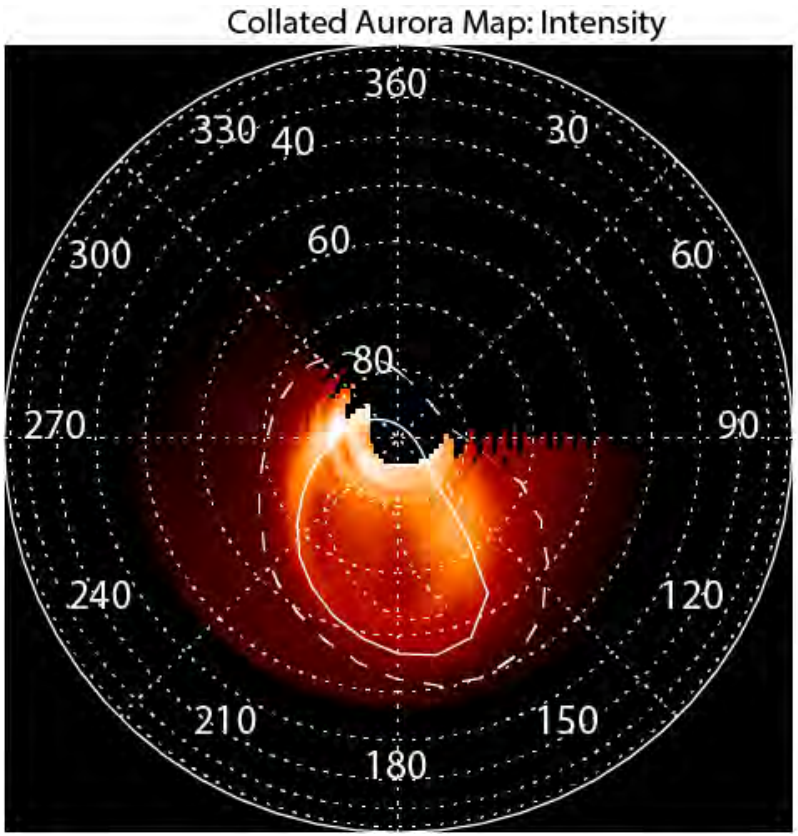
Ion winds

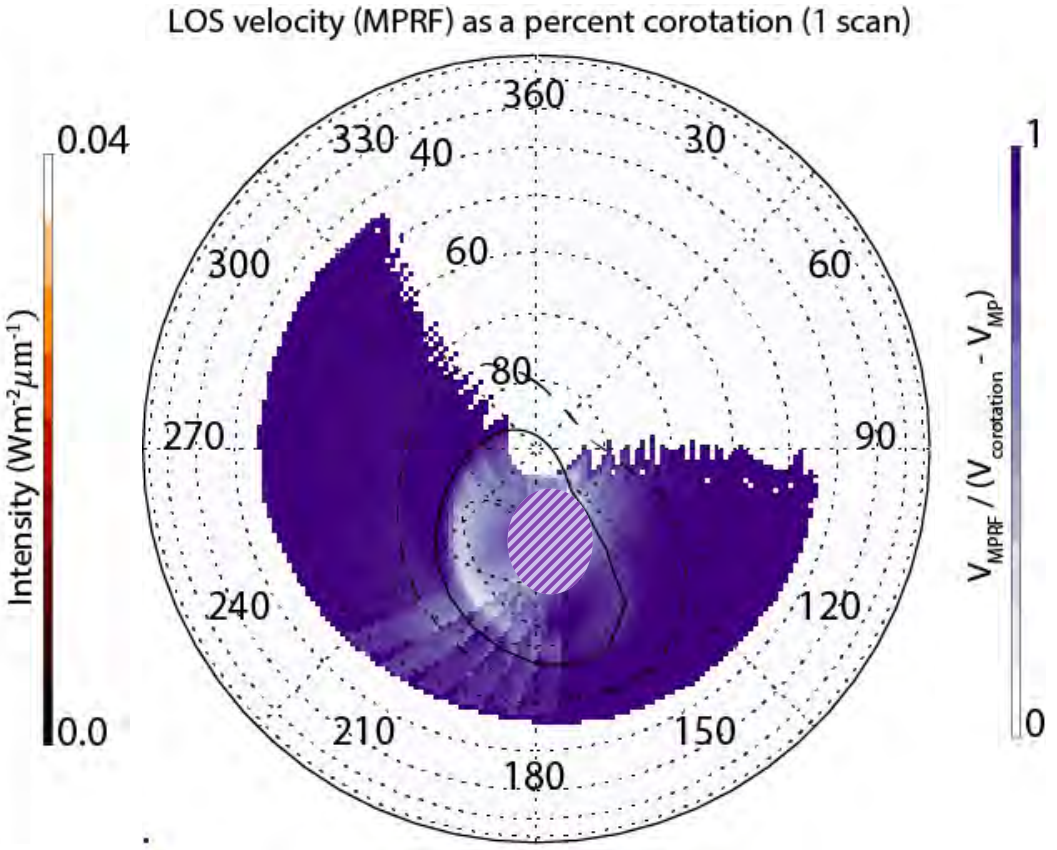


near IR	Johnson	IRTF /CSHELL	high-res. scanning spectroscopy of H_3^+ auroral emission.	observations scheduled on February 3, 5, 10, 15, 17, 22, 27 and March 5
near IR	Kita	IRTF / CSHELL	high-resolution spectroscopy of H_3^+ auroral emission	six half-nights scheduled: April 22, 25; May 7, 9, 19, 21

Johnson, in preparation

Ion winds





near IR	Johnson	IRTF /CSHELL	high-res. scanning spectroscopy of H_3^+ auroral emission.	observations scheduled on February 3, 5, 10, 15, 17, 22, 27 and March 5
near IR	Kita	IRTF / CSHELL	high-resolution spectroscopy of H_3^+ auroral emission	six half-nights scheduled: April 22, 25; May 7, 9, 19, 21

Johnson, in preparation

3 micron CH_4 emission

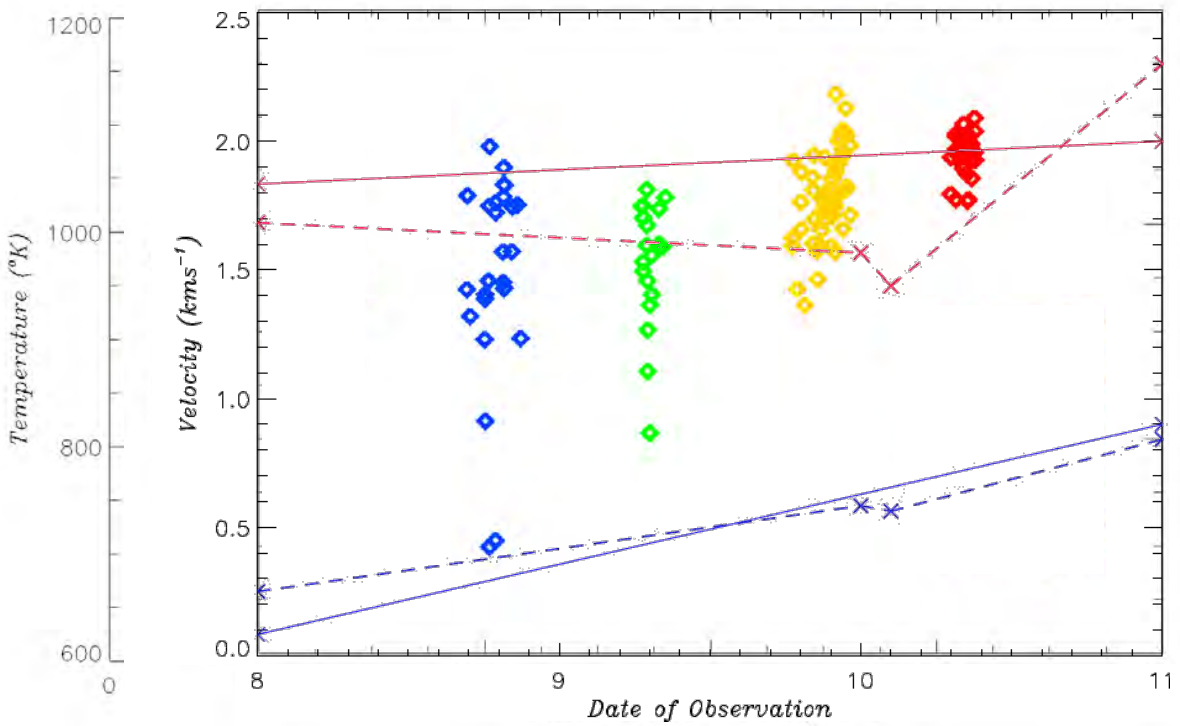
• The atmosphere is being heated at very low altitudes by auroral processes

or

• Intense auroral precipitation is resulting in convection or advection of methane from the deeper atmosphere to much higher altitudes.

near IR	Kim	Gemini S/ Phoenix	3-µm spectroscopy of auroral-related CH4, hydrocarbons.	16.7 hours granted for service time between April 25 and May 20.

Lystrup, 2008

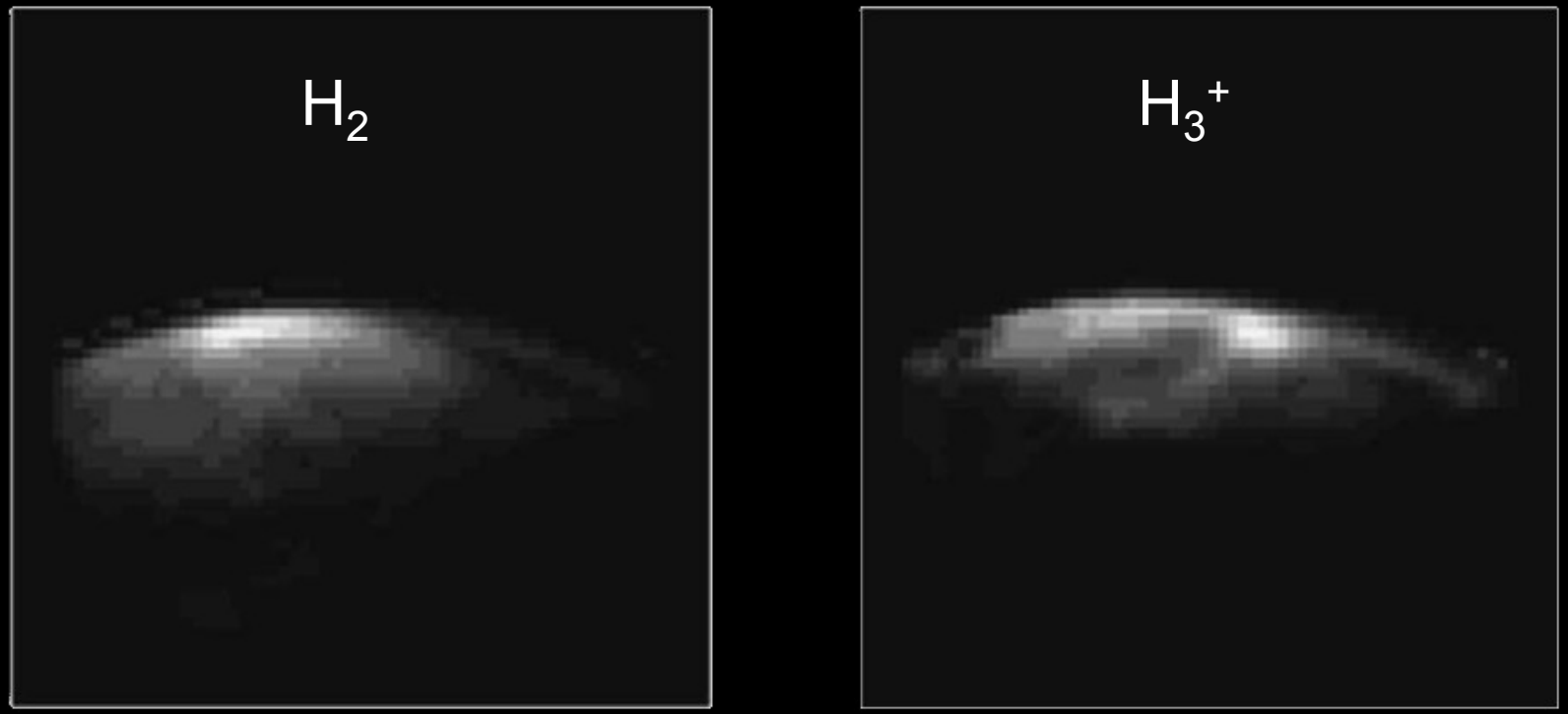


Stallard et al., 2001; 2002

Heating/cooling term	8 September	11 September
Joule heating and ion drag	67.0 mW m−2	277.0 mW m−2
Particle precipitation	10.8 mW m−2	12.0 mW m−2
Downward conduction	(−)0.3 mW m−2	(−)0.4 mW m−2
E(H_3^+) cooling	(−)5.1 mW m−2	(−)10.0 mW m−2
Hydrocarbon cooling	(−)65.5 mW m−2	(−)103.3 mW m−2
Net heating rate	7.4 mW m−2	175.3 mW m−2

Melin et al., 2005

2 micron H_2 quadrupole emission

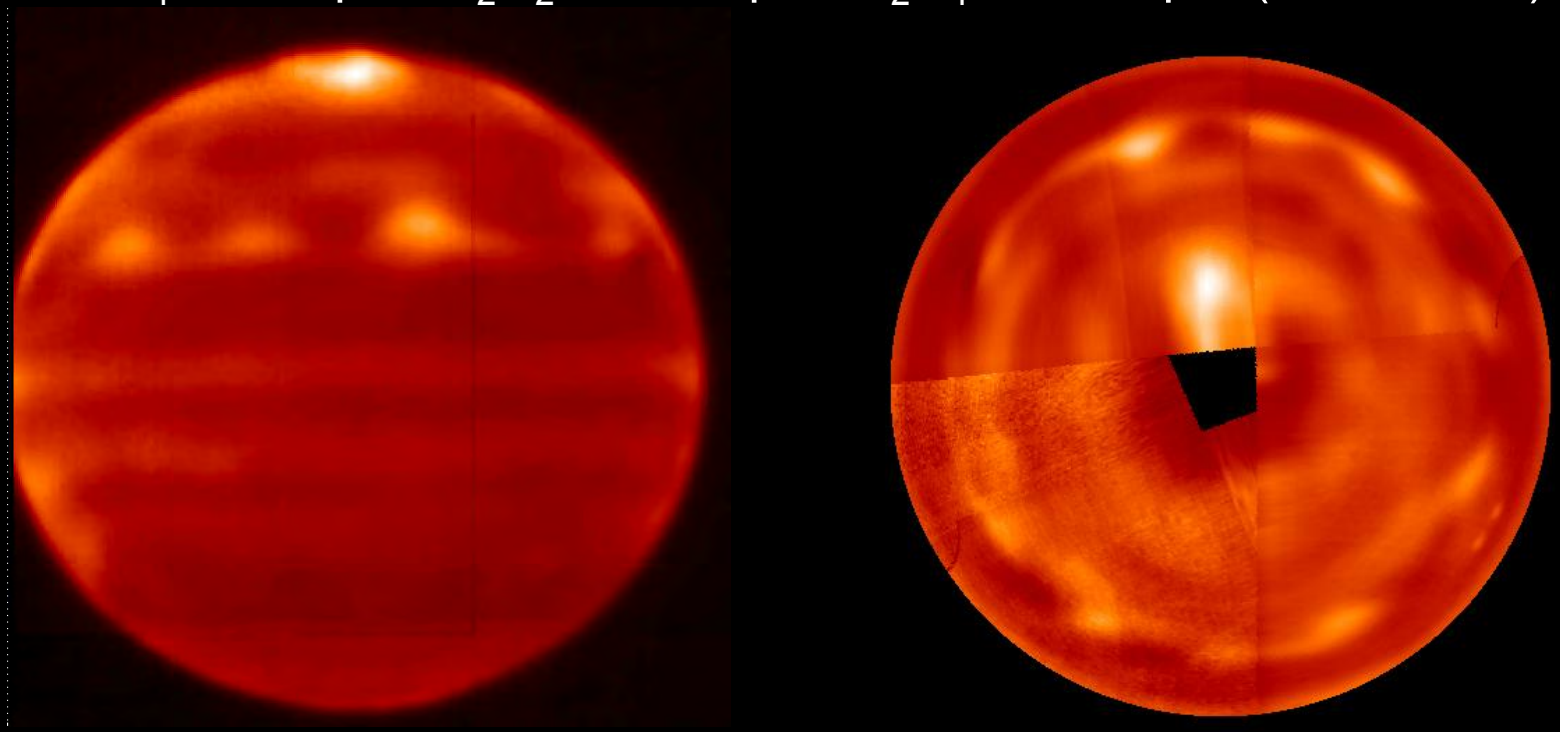


Raynaud et al., 2004

near IR	Defrère	LBT / LMIRCAM + NOMIC (7.9 µm)	AO imaging of 2 micron H2 and H3+ emission	scheduled for the last week of December and the last week of January and 5 blocks starting in March

Hydrocarbon thermal emission

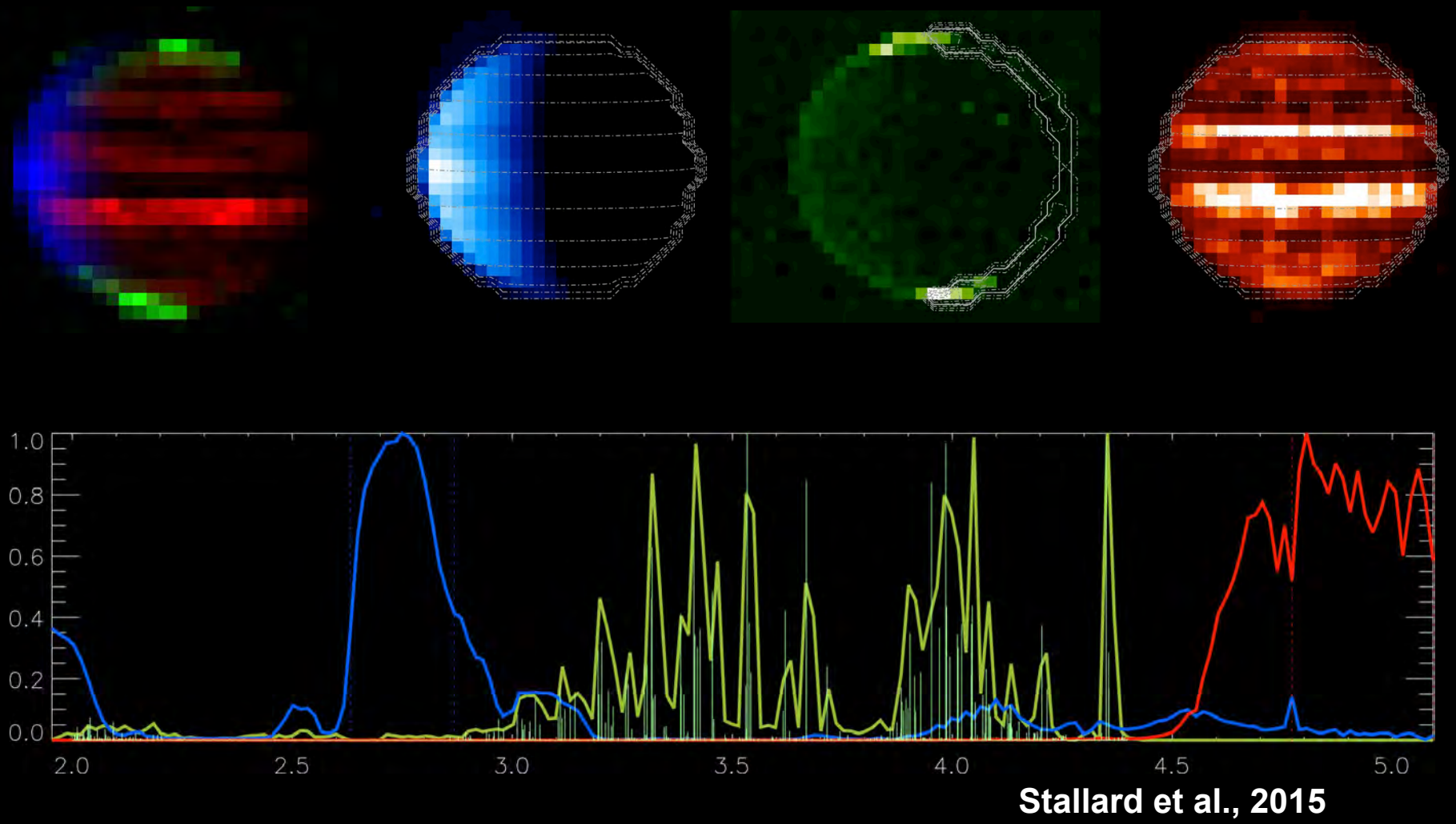
– CH_4 at 7.7 μm, C_2H_2 at 13.2 μm, C_2H_4 at 10.5 μm (sometimes)



Kasaba: Subaru COMICS CH_4 image and polar projection

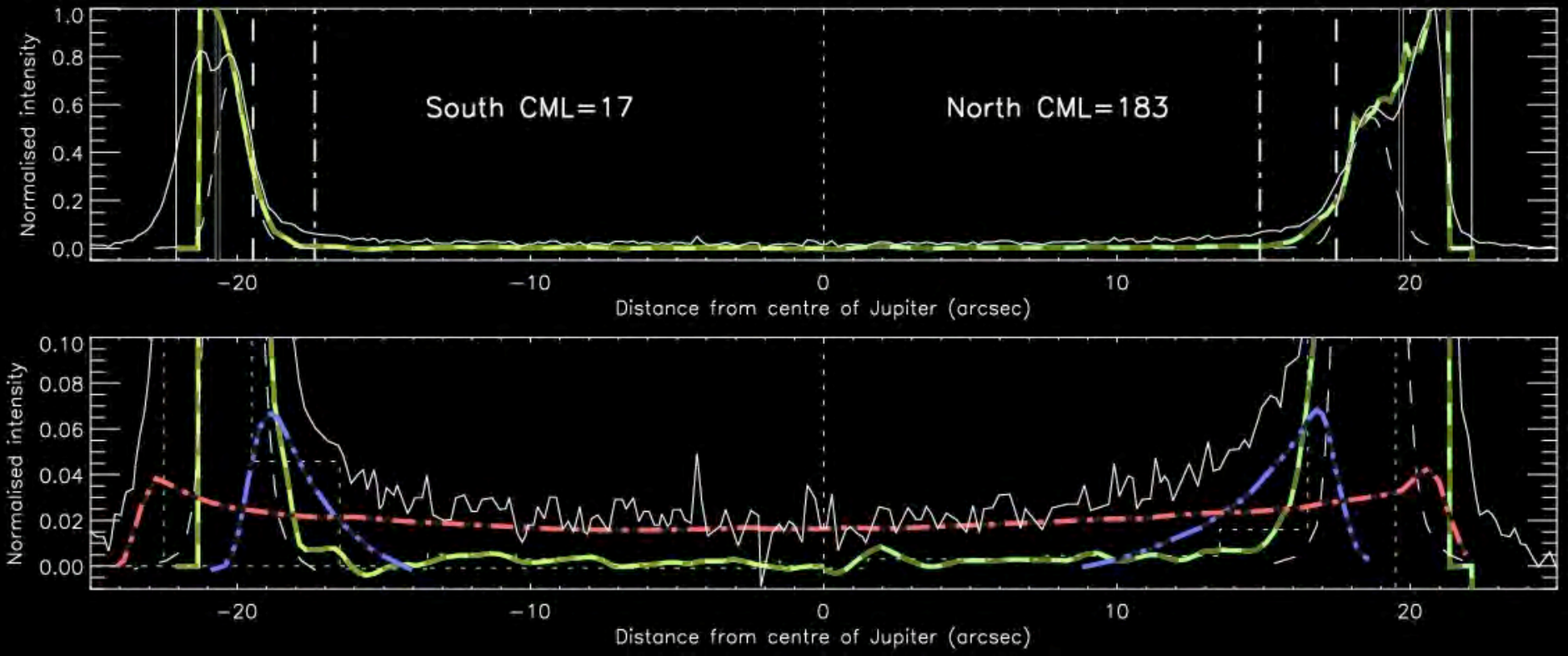
mid IR	Kasaba/Sinclair	Subaru / COMICS	stratospheric methane emission in polar auroral regions.	Acquired 2016 Jan 23-24 in very good weather conditions.
mid IR	Fletcher	VLT / VISIR	auroral heating and chemistry	observations acquired 2016 Feb 15-16, further obs. In March, May and July
mid IR	Sinclair/Greathouse/ Fletcher	IRTF / TEXES	spectroscopy to map stratospheric polar auroral regions.	scheduled for TEXES block: April 27 – May 6.
mid IR	Kostiuk	HIPWAC	ultra high-resolution spectroscopy of stratospheric emission	scheduled in HIPWAC block at the IRTF: April 18-21

Jupiter's nightside IR emission



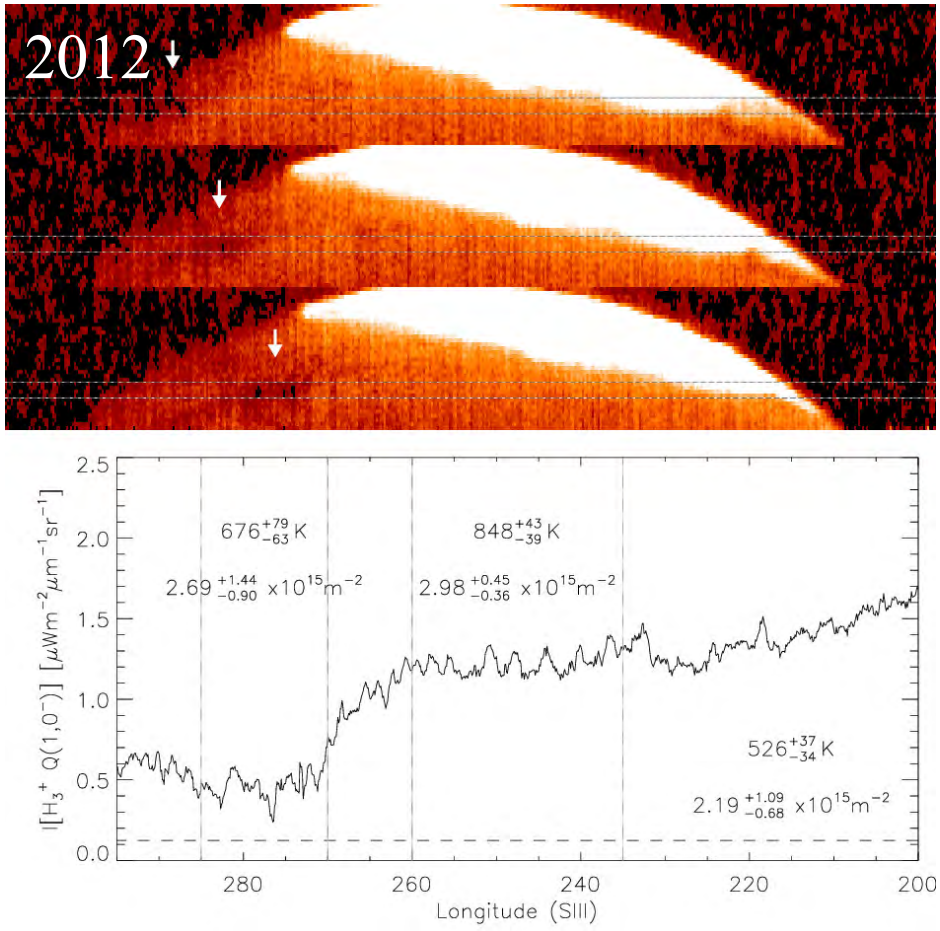
Stallard et al., 2015

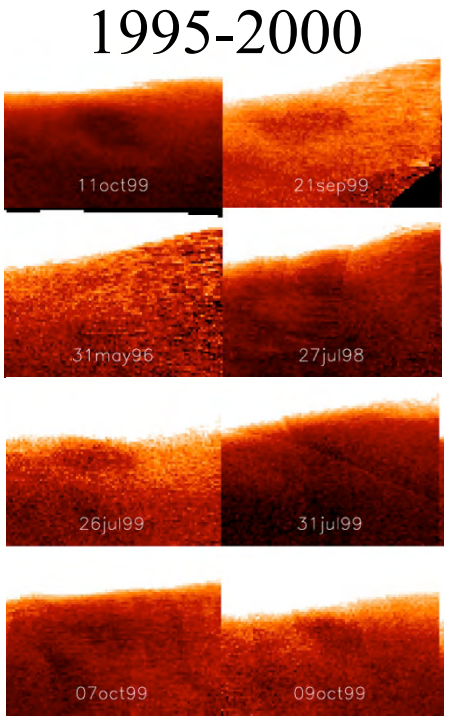
No evidence of auroral emission equatorward of the Io spot



Stallard et al., 2015

Great Dark Spot: thermosphere weather?

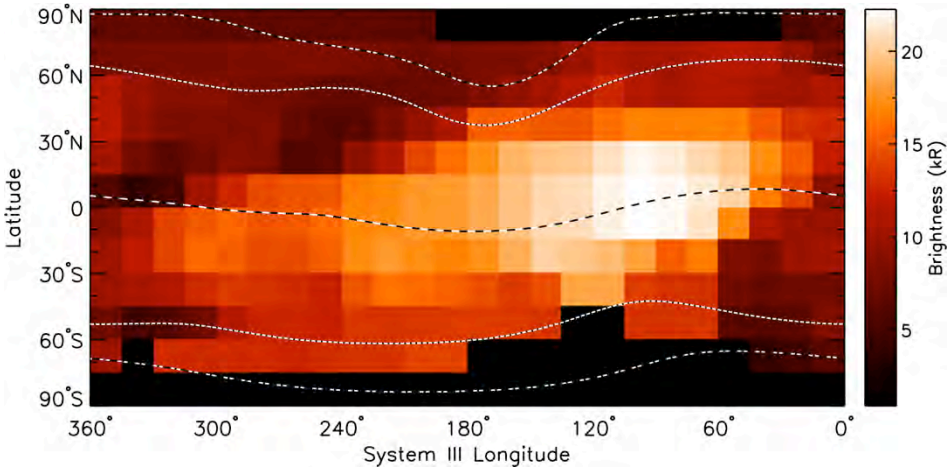




Stallard et al., in preparation

Equatorial emission

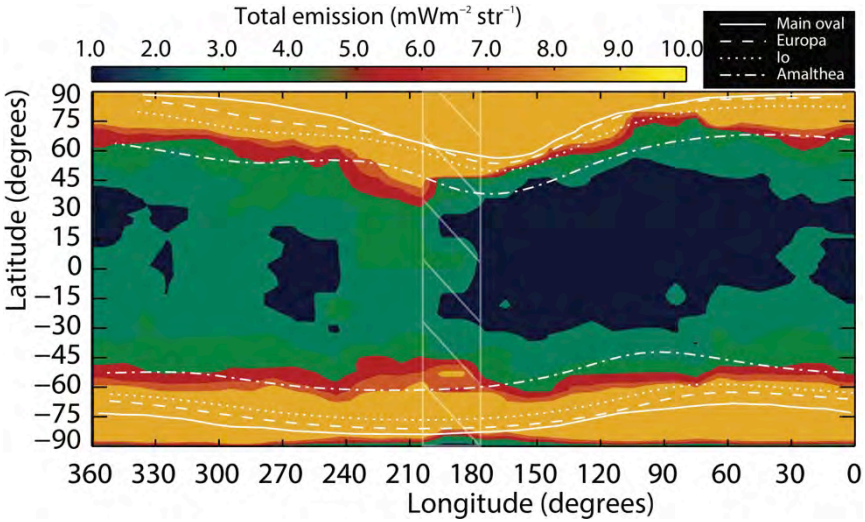
H Lyman-α bulge



Melin et al., in preparation

Henrik Melin, hpm5@leicester.ac.uk

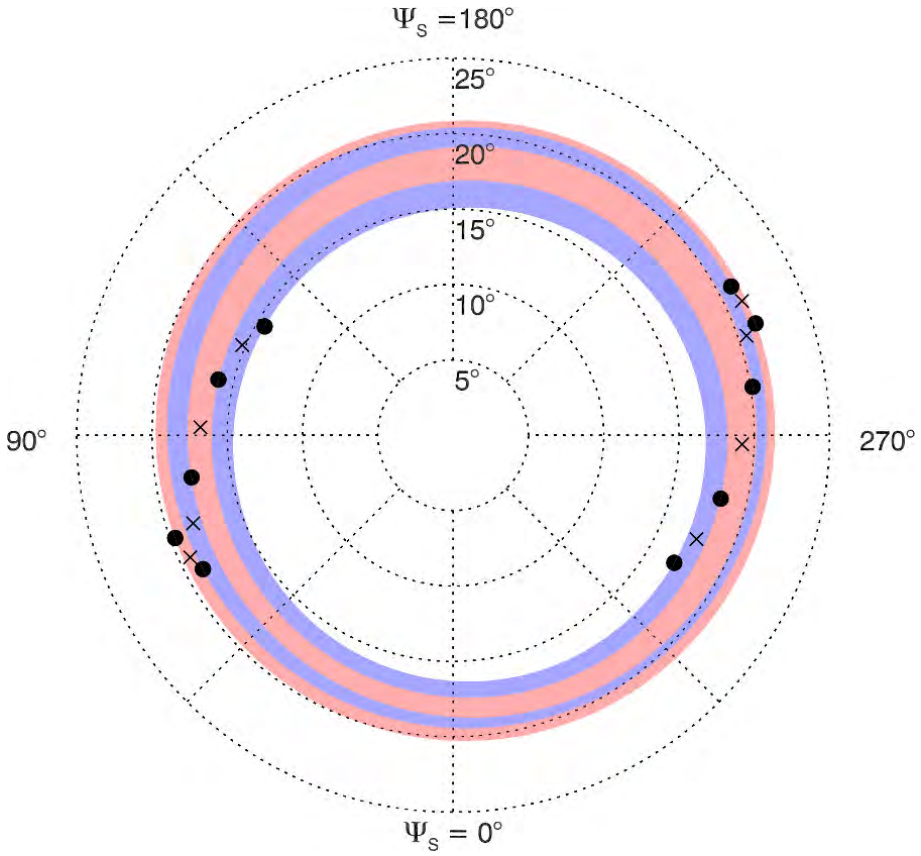
H_3^+ total emission

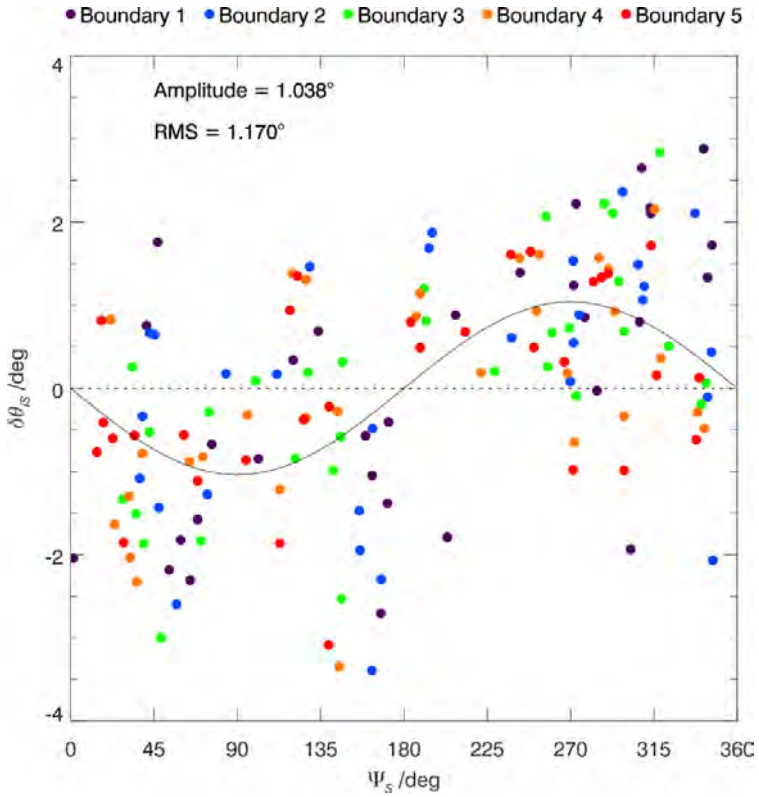


O'Donoghue et al., in preparation

James O'Donoghue, jameso@bu.edu

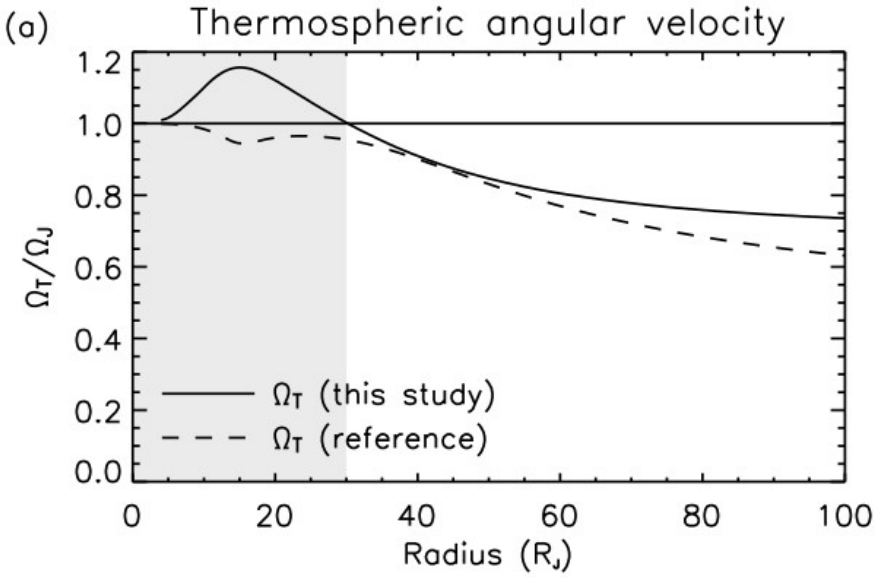
Saturn's planetary period oscillations

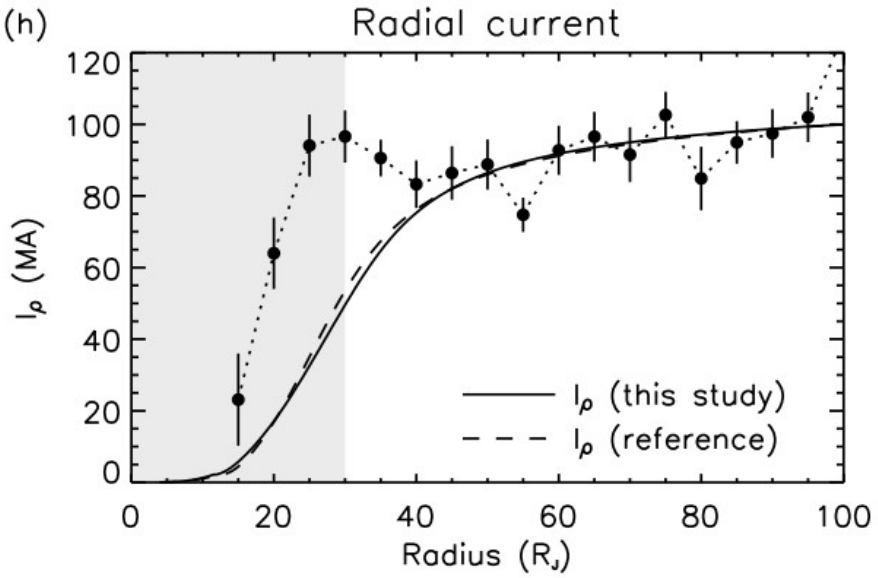




Hunt, 2014

Jupiter's thermosphere should drive significant changes within the inner and middle magnetosphere





Smith and Aylward, 2009

Period: Jupiter Approach (2015 November 1 – 2016 July 3 [JOI-2d]				
Spectral Region	**PI**	**Facility/ Instrument**	**Description**	**Date Scheduled/ Requested**
CCD + near IR	**Orton**	**IRTF/MORIS, SpeX guide camera and spectrometer**	**filtered imaging and spectral scans: 0.8-2.5μm, 2.5-5.1μm (SpeX)**	**Ongoing throughout Juno mission**
near IR	**Orton**	**IRTF/SpeX guide camera**	**filtered auroral imaging by IRTF staff 20- to 30-min intervals**	**Ongoing throughout Juno mission**
near IR	Defrère	LBT / LMIRCAM + NOMIC (7.9 μm)	AO imaging of 2 micron H2 and H3+ emission	scheduled for the last week of December and the last week of January and 5 blocks starting in March
near IR	**Johnson**	**IRTF /CSHELL**	**high-res. scanning spectroscopy of H3+ auroral emission.**	**observations scheduled on February 3, 5, 10, 15, 17, 22, 27 and March 5**
near IR	Kita	IRTF / CSHELL	high-resolution spectroscopy of H3+ auroral emission for velocity-field measurements.	six half-nights scheduled: April 22, 25; May 7, 9, 19, 21
near IR	Kasaba	Subaru / IRCS	AO-guided imaging/spectroscopy of H3+ emission	scheduled: May 19, 21, 24
near IR	Kim	Gemini S/ Phoenix	3-μm spectroscopy of auroral-related CH4, hydrocarbons.	16.7 hours granted for service time between April 25 and May 20.
near IR	O'Donoghue	Keck / NIRSpec	high-spectral resolution scanning of H3+ aurorae	scheduled for 4 half nights in May.
near IR	Bonfond	VLT / NACO	AO-imaging of H3+ emission	service observations to cover ten 1-hour sessions in Apr, May
mid IR	**Kasaba/ Sinclair**	**Subaru / COMICS**	**stratospheric methane emission in polar auroral regions.**	**Acquired 2016 Jan 23-24 in very good weather conditions.**
mid IR	**Fletcher**	**VLT / VISIR**	**auroral heating and chemistry**	**observations acquired 2016 Feb 15-16, further obs. In March, May and July**
mid IR	Sinclair/ Greathouse/ Fletcher	IRTF / TEXES	spectroscopy to map stratospheric polar auroral regions.	scheduled for TEXES block: April 27 – May 6.
mid IR	Kostiuk	HIPWAC	ultra high-resolution spectroscopy of stratospheric emission in polar regions	scheduled in HIPWAC block at the IRTF: April 18-21

Post-JOI observations

	Start time (VIT4)	Poor conditions		Clear conditions	
orbit00	2016-07-04T19:19:00	2:49	169	0:19	19
orbit01	2016-08-27T09:03:00	0:10	10	0:00	0
orbit02	2016-10-19T11:35:00	0:12	12	0:00	0
orbit03	2016-11-02T12:40:00	1:00	60	0:00	0
orbit04	2016-11-16T10:26:00	1:51	111	0:00	0
orbit05	2016-11-30T12:01:00	2:44	164	0:18	18
orbit06	2016-12-14T07:16:00	3:38	218	1:11	71
orbit07	2016-12-28T05:06:00	4:32	272	2:04	124
orbit08	2017-01-11T06:19:59	5:25	325	2:58	178
orbit09	2017-01-25T08:01:59	6:16	376	3:50	230
orbit10	2017-02-08T03:39:59	7:06	426	4:41	281
orbit11	2017-02-22T04:11:59	7:55	475	5:31	331
orbit12	2017-03-08T02:24:59	8:43	523	6:21	381
orbit13	2017-03-22T04:08:59	9:32	572	7:10	430
orbit14	2017-04-04T22:48:59	9:38	578	7:20	440
orbit15	2017-04-18T23:48:59	10:22	622	7:20	440